



DEFENSE STANDARDIZATION PROGRAM

CASE STUDY

Alternative Sustainable Plating for Electrical Connectors



This case study describes how the Defense Logistics Agency (DLA) Land and Maritime partnered with industry to help develop specifications for three new finishes for plating electrical connectors. These new finishes are intended to meet the same stringent requirements as the widely used, but hazardous, cadmium finish. The materials were added to nine military specifications covering hundreds of standardized military connectors.

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BACKGROUND

Cadmium has historically been one of the most widely used finishes for aluminum and steel electrical connectors and for connector accessories, such as back-shells and protective covers. Cadmium provides outstanding corrosion protection, as well as the electrical conductivity and durability needed for connectors exposed to harsh environments commonly encountered by warfighters. Other common DoD uses for cadmium finishes include fastener plating and metallic parts on all types of weapon systems.

Although it has many desirable characteristics, cadmium is carcinogenic, posing a great threat to health and safety. Exposure to cadmium has been linked to liver and kidney damage and is also associated with lung cancer. Therefore, many governments and industries have taken steps to reduce and, ultimately, eliminate cadmium from manufactured products and systems. For example, a European Economic Community directive of September 1983 dealt with effluent discharges and set limits for electroplating wastes. In Canada, inorganic cadmium compounds were placed on the Toxic Substances List that is part of the Canadian Environmental Protection Act passed in 1999.

The European Union has continued to be a driving force in setting health-protective standards in the use of hazardous materials. In particular, the July 2006 “Restriction on the Use of Hazardous Substances (RoHS)” is a directive for new electrical and electronic equipment containing more than certain levels of six banned substances, including cadmium and hexavalent chromium. This directive has affected manufacturing worldwide. Today, most major vendors offer RoHS-compliant materials so





they can continue to supply the large European consumer electronics market.

The United States has taken similar actions. Several executive orders (EOs) have addressed the reduction of hazardous substances. For instance, in January 2007, President Bush signed EO 13423, “Strengthening Federal Environmental, Energy, and Transportation Management.” This EO required government agencies to reduce the quantity of toxic and hazardous chemicals and materials that are acquired, used, or disposed. In October 2009, President Obama issued EO 13514, “Federal Leadership in Environmental, Energy, and Economic Performance,” which raised the stakes for environmental stewardship. In addition, EOs 13423 and 13514, as well as memorandums from the Office of the Under Secretary of Defense (OUSD) for Acquisition, Technology and Logistics (AT&L), required DoD to reduce the quantity of toxic and hazardous chemicals and materials acquired, used, or disposed. Another OUSD(AT&L) memorandum, issued in April 2009, mandated that hexavalent chromium not be used without a waiver.

PROBLEM

The corrosion engineering community has long understood the health, safety, and environmental concerns with cadmium and has significantly reduced its use over the past 25 years. Further, legislative pressure and logistics issues have forced the aerospace and military agencies to adapt to the increasingly restrictive standards.

DoD has made some progress in minimizing the use of hazardous materials. For instance, some newer weapon systems programs have sought to eliminate or severely reduce their use. Notably, the Joint Strike Fighter program is the first major weapon system planned to be cadmium free. The *Zumwalt*-class destroyer program also has expressed interest in reducing the use of cadmium. Yet attempts to completely eliminate cadmium have not been completely successful, primarily because of the difficulty of finding viable alternatives. Therefore, DoD continues using cadmium in many of its weapon systems while it conducts further research to identify and evaluate alternatives to cadmium plating.

Finding alternative finishes for electrical connectors, which have stringent performance requirements, has been particularly problematic. Electrical connectors need to be corrosion and abrasion resistant, as well as electrically conductive to shield against electromagnetic interference and radio frequency interference.

Electrical connectors used in aircraft—sometimes as many as 2,000—come in a wide variety of shapes, sizes, configurations, and materials. Typically, they are constructed of aluminum, titanium, stainless steel, or composite materials. Cadmium plating is usually applied to connectors used in Air Force and Navy weapon systems, as well as in Army ground systems, because it is an excellent corrosion inhibitor and has relatively high electrical conductivity. A chromate conversion coating is often applied for additional corrosion protection.



In response to the need for a plating solution for electrical connectors that meets the requirements of legislation and executive orders, as well as military requirements, DLA Land and Maritime—the preparing activity for numerous electrical connector military specifications—undertook the task of identifying and standardizing plating alternatives that are free of cadmium.

APPROACH

The Circular Connector Group, part of the Interconnection Branch at DLA Land and Maritime, led the effort to minimize the use of hazardous materials for plating electrical circular connectors. Specifically, the group led a significant standardization effort to develop alternative materials for plating electrical connectors that meet the same stringent corrosion resistance, system compatibility, durability, and electrical performance requirements as the widely used, but hazardous, cadmium finish.

The Circular Connector Group partnered with SAE International’s Connectors Committee (AE-8C1), which is a non-government standards developing organization (SDO). AE-8C1, consisting primarily of original equipment manufacturers (OEMs) and leading manufacturers of military-qualified connectors, is dedicated to creating, preparing, and maintaining a wide variety of specifications, standards, and requirements for connectors and connector accessories used in military and commercial applications.


Broadly speaking, the DLA–SAE team took the following approach:

- Identify finishes with the potential to be alternatives to cadmium.
- Run corrosion tests against the criteria capturing the important corrosion-protection characteristics of cadmium.
- Identify the best-performing alternatives.
- Add the alternatives to the appropriate military and SAE connector specifications.

It was clear from the beginning that no single coating could replace cadmium in all applications. Engineers realized that the protective function of the coating needed to be specifically determined for a given application so that an alternative coating could be selected. In addition to technical performance, they considered other important factors, such as the overall cost and availability of the alternative coating technology. One concern was to avoid proprietary technologies, which usually limit availability and complicate logistics.

The DLA–SAE team identified many alternative finishes for corrosion testing. The most promising candidate coating processes to replace cadmium in electrical connector applications were those already being used on electrical connectors and those with both considerable promise for the application and sufficient maturity.

One of the most severe corrosion tests for electrical connectors is dynamic salt spray testing, which



includes a durability subtest that stresses the connector plating material. Following salt spray exposure, connectors must continue to meet all electrical test requirements. Any alternative finish must have the same electrical bonding (shell-to-shell conductivity) capability as cadmium, which is necessary for weapon system applications susceptible to electromagnetic interference. Finally, alternative finishes must perform at the same temperature range as cadmium finishes (-65° to 175° Celsius).

None of the candidate finishes performed as well as or better than cadmium in all tests. However, the DLA-SAE team identified three plating options as being the most suitable as replacements for cadmium. These connector plating/finish options are nickel fluorocarbon polymer, zinc nickel, and pure electrodeposited aluminum.

The DLA-SAE team added the three cadmium alternatives options to several military circular and rectangular connector specifications:

- MIL-DTL-22992, “Connectors, Plugs and Receptacles, Electrical, Waterproof, Quick Disconnect, Heavy Duty Type”
- MIL-DTL-24308, “Connectors, Electric, Rectangular, Non-Environmental, Miniature, Polarized Shell, Rack and Panel, General Specification for”
- MIL-DTL-26482, “Connectors, Electrical (Circular, Miniature, Quick Disconnect, Environment Resisting), Receptacles and Plugs”
- MIL-DTL-28840, “Connectors, Electrical, Cir-

cular, Threaded, High Density, High Shock, Shipboard, Class D”

- MIL-DTL-32139, “Connectors, Electrical, Rectangular, Nanominiature, Polarized Shell, General Specification for”
- MIL-DTL-38999, “Connectors, Electrical, Circular, Miniature, High Density, Quick Disconnect (Bayonet, Threaded, and Breech Coupling), Environment Resistant, Removable Crimp and Hermetic Solder Contacts”
- MIL-DTL-55181, “Connectors, Plug and Receptacle, Intermediate Power (Electrical, Waterproof), Type MW, General Specification for”
- MIL-DTL-83513, “Connectors, Electrical, Rectangular, Microminiature, Polarized Shell, Specification for”
- MIL-DTL-83723, “Connectors, Electrical (Circular, Environment Resisting), Receptacles and Plugs.”

The team also added the three plating options to dozens of associated military specification slash sheets.

- MIL-DTL-24308, “Connectors, Electric, Rectangular, Non-Environmental, Miniature, Polarized Shell, Rack and Panel”
- MIL-DTL-83513, “Connectors, Electrical, Rectangular, Microminiature, Polarized Shell.”

At the same time, SAE revised its Aerospace Standard (AS) 85049, “Connector Accessories,



Electrical, General Specification for,” a specification for accessories designed for and intended for use with military circular connectors. In addition, in 2011, SAE began the process to update AS50151 to add the alternative finishes.

These basic specifications cover hundreds of standardized connectors for use by the military and their OEMs and are among the most important military specifications for controlling circular and rectangular connectors used in weapon system interconnect applications. MIL-DTL-38999 alone is used in more than 635 weapon systems and accounts for thousands of dollars in DLA sales each year. In addition, more than 7,000 national stock numbers are associated with the specification.

CHALLENGES

This specification standardization development process required effective coordination with more than 100 individuals representing several military departments, connector manufacturers, equipment manufacturers, and SDOs.

One primary challenge to implementing this technology is for military users to evaluate how to integrate connectors with alternative plating options into their applications. In some cases, military users have applications with corrosion environments that are above and beyond the specification requirements. Also, in legacy systems, there may be compatibility issues (for example, the plating on the panel that the connector is mounted on may not be


galvanically compatible with the connector plating material). These types of issues must be reviewed and evaluated by users in order to select the best connector that will meet their needs.

OUTCOME

The three new connector plating materials are intended to meet the same performance requirements as cadmium plating without the potential hazards to our warfighters. These connectors are expected to provide the military and industry with the sustainable, cadmium-free electrical connectors they need for use in hundreds of demanding military systems.

Since the addition of the new finishes to the military specifications, several connector manufacturers have taken action to seek qualification of their products with new plating options, and several have





been added to the appropriate qualified products list (QPL). Below are some examples:

- Amphenol Aerospace connectors with nickel fluorocarbon polymer finishes have been added to QPL-38999.
- Souriau connectors with zinc-nickel finishes have been added to QPL-38999, and its connectors with zinc-nickel plating have been added to QPL-26482.
- Glenair connectors with pure electrodeposited aluminum have been added to QPL-83513.

BENEFITS

These standardized parts are expected to facilitate lower procurement costs, shorter procurement lead-times, increased operational readiness, and a reduced logistics footprint, and they will reduce the total life-cycle costs of systems. The standardized products will also facilitate competition among connector manufacturers. In addition, standard parts can be used across multiple platforms to advance the goal of interoperability among the military services. An added benefit will be multiple qualified manufacturers under the QPL for these connectors, which will result in improved supply availability for many years.

The project will preclude the costly piecemeal introduction of nonstandard parts. Precluding the introduction of just 100 nonstandard parts annually will result in a cost avoidance of more than \$2 million each year.

CURRENT STATUS

An ad hoc working group—consisting of DLA Land and Maritime, SAE, Navy, Air Force, and Army, along with manufacturers and OEMs representing ships, submarines, and aircraft—continues to address the identification of alternatives to the use of hazardous materials.

The team is continuing its efforts to determine which alternative plating options present the most compatible alternative to cadmium in existing systems. The team also networks with and assists other interested parties with determining which plating alternatives provide the best option for weapon systems still being developed.

The circular and rectangular connector specifications have been dated and approved and are available from DLA Document Services on the ASSIST website: <https://assist.dla.mil/online/start/>. Several manufacturers are in the process of qualifying additional products to these specifications.

The Naval Air Systems Command is conducting beachside atmospheric exposure testing at the Kennedy Space Center test site as an additional validation of the new connector alternative plating options.

The Circular Connector Group has continued its work on hazardous material minimization issues related to cadmium plating of connectors. For instance, during the development of a new Defense



Federal Acquisition Regulation Supplement clause (published in May 2011) for the minimization of hexavalent chromium, a team member provided input on behalf of DLA Land and Maritime and coordinated efforts with SAE's AE-8C1.

The same team member participated in DoD's ongoing Advanced Surface Engineering Technologies for a Sustainable Defense (ASETSDDefense) initiative. ASETSDDefense brings together key players from the military departments and industry to share information and technical data from research and testing of military weapon system subcomponents, including electrical connectors and fasteners. In August 2012, an ASETSDDefense workshop was held to inform attendees about the emerging cadmium plating alternatives, to arrive at a collective understanding of the related issues, to define requirements for various applications, and to help coordinate future research, development, test, and evaluation efforts to bring the best options to production.

After decades of investments by DoD and aerospace companies, environmentally friendly alternatives to cadmium plating used for corrosion protection of weapon systems components are coming into production. More work is required to demonstrate that the coating will be acceptable for connectors under all likely conditions.

Recently, a new electroplated alloy coating has emerged. That coating, based on a zinc-nickel chemistry, was developed for the automotive

industry. Modified for aerospace use, a low hydrogen embrittlement version with trivalent sealer appears to meet, and in some cases exceed, all of the requirements for cadmium on landing gear and other high-strength aircraft alloys. This plating chemistry is available from several vendors, although only two have been qualified to date. Both Boeing Defense and Hill Air Force Base, UT, have qualified the coating for landing gear, and Hill Air Force Base is moving forward with scale-up and implementation for across-the-board cadmium replacement for Air Force landing gear sustainment.

FUTURE EFFORTS

Recognizing that cadmium regulations are going to become more stringent as a necessity for the long-term health of society and the desire to minimize





downstream DoD costs, several actions are appropriate for consideration by the corrosion control community:

- Identify opportunities to use alternative materials in the design, manufacturing, and maintenance of weapon systems.
- Catalog the corrosion resistance requirements.
- Specify the materials for a wide range of applications.
- Understand the inherent corrosivity of different applications.
- Keep abreast of changes in industry.
- Develop specifications, drawings, and maintenance documentation for alternative products.
- Analyze corrosion control performance versus environmental requirements.

LESSONS LEARNED

Teamwork is essential. The DLA–SAE team identified the key stakeholders with respect to the technologies involved, engaged those stakeholders, and worked collectively to identify, test, and approve acceptable alternatives.

Requirements must be fully understood. The DLA–SAE team identified the operating environments and the requirements necessary to operate in those environments. The team also worked with all key players to make certain the requirements of each would be met.

Persistence pays off. The team found the road to success was long, complex, and difficult, but through hard work and determination, it achieved success.





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